3.0 SUMMARY OF ASSUMPTIONS, LIMITATIONS, AND ERRORS

This section of ASP-I summarizes assumptions, limitations and known errors of TRAP and addresses the implications of these for model use or application. This information is useful in helping a user to determine if the model adequately addresses all the phenomena and environmental conditions that are important to the intended application. These assumptions, limitations, and errors are derived from any and all applicable sources (including model documentation and V&V reports).

A detailed listing of assumptions, limitations, and errors by functional element is contained in Appendix G. The reader is referred there for a detailed discussion of the impact of assumptions, limitations, and errors in a particular area of the model.

NAIC's perspective on TRAP is also presented so the user may fully understand the intended use of the model and therefore, not apply the model to solve a class of problems for which it is entirely unsuited. The following paragraphs, excerpted or paraphrased from [21], outline the general philosophy behind TRAP.

a. Although often referred to as an "engagement" model, TRAP does not strictly model an engagement. Only the launch aircraft carries a weapon and, although ground and airborne targets can be modeled, this is only to the extent that they provide a target to which the missile can be guided.

b. The assessment of missile performance is the prime objective of the overall model. The level of fidelity in the various parts of the model is only intended to be sufficient to obtain the correct airframe response of the missile while it is intercepting a representative target in a benign environment.

c. Because TRAP is mainly used to assess the performance of threat missile systems, the simulation is biased towards the worst case (or most capable threat) scenario. For instance, TRAP uses simplified seeker signal processing and a benign electromagnetic environment, i.e., the modeling of jammers is mainly to provide a target for passive or home-on-jam seekers rather than to apply deceptive jamming to other classes of seekers. Similarly, some phenomena that may adversely affect the behavior of the missile are not modeled because it is assumed that because the missile is operational, these areas do not present a significant limitation on the performance of the missile. An example of this would be the passage of the missile through the aircraft flowfield following launch, which is not modeled in TRAP.

d. The model incorporates different levels of fidelity so that an appropriate level of fidelity can be chosen to match either the quality of the available data (e.g. point-mass or 6-DOF aerodynamics), or a particular application of the model (multiple runs to generate maximum missile launch ranges or modeling of a single engagement geometry). In general, if the model is run in a lower fidelity mode, there will be a greater number of assumptions employed, and the analyst must be aware of these to properly interpret model results.

e. Some apparent limitations exist simply because there has not yet been a need to model a particular feature. New features are added as needed to model a specific missile system. This is typically followed by the incorporation of the feature in a generic form that can then be used to develop similar capabilities for other missile systems in the future.

f. Some parts of the model may be in error because a generic feature has been incorporated in the past but has never been used (e.g., some of the guidance and autopilot options). These areas of the model may present a problem to a user expecting to use these functions to perform model development.

g. When TRAP is used in a production mode using a previously developed and tested model, the effect of these assumptions and limitations has been taken into account by the developer. If the user of such a model operates within the constraints specified by the model developer, he can expect the model to provide accurate results.

3.1 ASSUMPTIONS

This section summarizes the assumptions listed in published sources or those reported by model users and developers. Other assumptions may become apparent if a more detailed examination of the code is required for a subsequent phase in the model accreditation process.

The contents of this section are closely linked with the following section on limitations as many of these assumptions imply some limitation on the use of the model. In such cases, the limitation is indicated under the heading of "Implications for Model Use". In general, these limitations are not repeated in Section 3.2.

TABLE 3-1. TRAP Assumptions By FE.

FA/ FE#	Functional Area/ FE Name	Assumption	Implications for Model Use
I	Target Aircraft		
1.2	Movement	Modeled as point mass	Detailed aircraft dynamics not modeled
1.3.3	RF Signature	For the bistatic case (illuminator and receiver not collocated), RCS is approximated by using the static value at an aspect midway between illuminator-to-target LOS and receiver-to-target LOS	Lower fidelity model allows use of monostatic RCS tables which are much smaller than bistatic ones
5.1.1	On-Board Jammer	Antenna orientation remains fixed relative to target aircraft	Antenna steering not modeled
5.1.3	Off-Board Jammer	Position of ground-based jammers does not change (regardless of specified velocity); antenna orientation fixed	Position updates incorrect if velocity is non-zero; antenna steering not modeled
II	Launch Aircraft		
1.2	Movement	Modeled as point mass	Detailed aircraft dynamics not modeled

TABLE 3-1. TRAP Assumptions By FE. (Contd.)

FA/ FE#	Functional Area/ FE Name	Assumption	Implications for Model Use
2.4.1	Transmitter (for semi-active missile)	Illuminator on-board launch aircraft aligned with AI radar	Illumination from other sources not modeled
III	Missile		
1.1.1	Mass Properties	Constant center of gravity (Cg) assumed for propellant during motor burn	Cg for end burning rocket motors not modeled correctly (affects maneuverability during motor burn only)
1.1.2	Moments of Inertia	Products of inertia are assumed to be zero (this greatly simplifies the equations of motion)	Valid for missiles with two planes of symmetry or where level of asymmetry is small enough that products of inertia can be neglected.
1.2	Movement	Missile has zero body roll angle	Rolling airframe and bank-to-turn missiles not modeled
		Equations of motion (EOM) assume flat, non-rotating Earth	Significant only for missiles with long cruise periods at high speeds (z-component dropped from translational EOM amounts to 2% of vehicle weight at Mach 3.0, more above)
		EOM break down as missile approaches vertical	Missile cannot fly through vertical
		Wind effects not modeled (missile true airspeed >> wind speed)	May be significant if position relative to ground location is important (ground targets) or for rapid changes in missile heading
1.2.2	Aerodynamics/ Kinematics	Aero characteristics are a function of trimmed AOA and sideslip	Transient (out-of-trim) response of missile not modeled; significant only for short range intercepts that require high lateral accelerations
		Point-mass: aero characteristics must be provided for the '+' configuration (in the fin planes)	User must conform to convention
		3 DOF pitch: aero characteristics must be provided in the xz-plane of the missile body-axes	User must conform to convention
		3 DOF yaw: aero characteristics must be provided in the xy-plane of the missile body-axes	User must conform to convention
		5 DOF: aero assumptions for 3 DOF pitch and yaw apply	User must conform to convention
		6 DOF: aero assumptions for 5 DOF apply, roll data entered as a function of Mach number (symmetrical) or Mach number and AOA (non-symmetrical)	User must conform to convention

TABLE 3-1. TRAP Assumptions By FE. (Contd.)

FA/ FE#	Functional Area/ FE Name	Assumption	Implications for Model Use
2.3.1	IR Seeker FOV	Guidance commands generated whether or not target in FOV	Optimistic seeker performance
2.4.2	RF Receiver	All receivers are four-beam monopulse systems	Other receiver types not modeled
2.4.5	RF Target Tracking	"Perfect" Doppler tracker (window centered on power-weighted Doppler frequency gate)	Not appropriate for investigation of ECM techniques
3.1	Warhead	Successful flyout occurs when PCA within input lethal radius	Fuze and warhead effects not modeled
6.1	Guidance	Control in all planes by aerodynamic control <u>or</u> TVC	Mixed control types not modeled
6.2	Autopilot	If TVC is used, body-attitude autopilot type with rate gyro assumed	Other autopilot types not supported for TVC missiles
IV	Environment		
	General	Uses standard atmosphere	Performance in non-standard conditions not modeled
1.1	Atmospheric Attenuation	Constant values (user input) used for absorption coefficients for oxygen and water vapor	User must input appropriate values for intercept conditions
1.3	Radiance/ Transmittance	Transmittance set to 1 (tables bypassed)	Optimistic lock-on ranges for IR seekers
2.1	Clutter	Power from illuminator sidelobes reflected into receiver sidelobes neglected	Minimal
2.2	Multipath	Indirect out - Indirect return path neglected, 180 phase shift for indirect path	Minimal (major contributors considered)
All	All	Right handed coordinate system, x-axis positive North, y positive East, z positive down; input altitudes specified as positive values	User must conform to convention
All	All	Body axes defined with origin at Cg, x-axis positive forward, y positive starboard, z positive down; some missile variables measured from nose (backwards)	User must conform to convention

3.2 LIMITATIONS

This section contains a summary of the limitations that have been identified in TRAP 3.1a, but addresses only those identified in published sources or reported by model users and model developers. Other limitations may become apparent during subsequent phases of the model accreditation process.

The contents of this section are closely linked with the assumptions listed in the previous section as many of those assumptions imply some limitation on the use of the model. In such cases, the limitation was indicated under the heading of “Implications for Model Use” under the appropriate assumption and has not then been repeated in this section. It is therefore recommended that the reader be familiar with Section 3.1 before reviewing the limitations identified in this section.

TABLE 3-2. TRAP Limitations By FE.

FA/ FE#	FE Name	Limitation	Impact
I	Target Aircraft		
	General	A maximum of two identical targets (with coordinated flight) can be simulated	Multiple, independent targets not modeled
1.2	Movement	Limited to pre-programmed maneuvers	User must select from existing maneuvers or generate new code to model required maneuver
5.1.1	On-Board Jammer	Airborne jammers may only be used if missile has semi-active or active radar seeker	Cannot be used as target for passive radar seeker
		Only one jammer per target aircraft (total of 2) and only 1 beam pattern for both jammers	No more than two jammers simulated
5.1.3	Off-Board Jammer	Ground-based jammers may only be used if missile has passive radar seeker	Cannot be used as target for semi-active or active radar seekers
		Maximum of 10 ground-based jammers	Not more than 10 jammers simulated
II	Launch Aircraft		
1.2	Movement	Limited to pre-programmed maneuvers	User must select from existing maneuvers or generate new code to model required maneuver
2.4	AI Radar	AI radar unaware of second target	Second target ignored
		AI radar model not fully tested in TRAP	Recommend not using
III	Missile		
1.2.1	Propulsion	Maximum of two propulsion stages modeled	New code would have to be generated to model more stages
1.2.2	Aerodynamics/ Kinematics	Launch transients (e.g., lateral acceleration due to ejection, flight through aircraft flowfield) not modeled	Missile must be launched within accepted launch constraints
		Missile assumed to be at zero body roll angle	Rolling airframe and bank-to-turn missiles not modeled
		Equations of motion break down as missile approaches vertical	Missile cannot fly through vertical
3.1	Warhead	Warhead and fuzing effects not modeled	Cannot be used for detailed fuze and warhead studies

TABLE 3-2. TRAP Limitations By FE. (Contd.)

FA/ FE#	FE Name	Limitation	Impact
6.1	Guidance	Only Cartesian controlled missiles (skid-to-turn) modeled in which pitch and yaw commands are generated	Cannot model bank-to-turn missiles
		Thrust vector control not modeled for point-mass missile	User must select higher fidelity model for TVC
All	All	When using smart search to determine launch envelope, search must progress from the best to worst case	May preclude search in one sweep, e.g., from nose to tail in generation of horizontal launch zone where point of least capability falls in middle of selected range of aspects

3.3 ERRORS AND ANOMALIES

This section summarizes the errors for TRAP 3.1a listed in the published documentation or reported by model users and developers. Other errors may become apparent during the more detailed examination of the code that may occur during subsequent phases of the model accreditation process.

It is important to note that there are some areas of the code that have not been fully tested; for example, the radar seeker and the AI radar. Although some errors have been identified in these areas of the code, they have not been reported here because there was insufficient documentation regarding the error and an in-depth analysis of the code was not performed to explore them.

TABLE 3-3. TRAP 3.1a Known Errors.

FA/ FE#	FE Name	Error	Impact
I	Target Aircraft		
1.2	Movement	Non-generic target has zero pitch angle regardless of input value	Initially straight and level (inputs ignored)
		Error in altitude control logic for s-turn maneuver	Target attains incorrect altitude somewhere between desired and initial altitude
1.3.2	IR Signature	Aspect angle for IR signature look up calculated incorrectly	User should input single value IR signature in POLICY routine
1.3.3	RCS	Aspect angle for RCS look up calculated incorrectly; look up not operational	User should input single value RCS in POLICY routine; Calculation currently commented out
II	Launch Aircraft		
1.2	Movement	For non-generic aircraft, incorrect values set for initial body and flight-path pitch angles	Aircraft pitch depressed by AOA at start of run
2.4	AI Radar	RCS table lookup not operational	User must set single value target RCS in POLICY routine

TABLE 3-3. TRAP 3.1a Known Errors. (Contd.)

FA/ FE#	FE Name	Error	Impact
2.4.2	Receiver	Error in initialization of system losses (set to zero)	No losses modeled
2.4.3	Antenna	Error in update to antenna LOS	Antenna motion is not possible
III	Missile		
1.2	Movement	Error in calculation of maximum lateral acceleration available (lateral acceleration may be used to terminate simulation)	Some flights may continue when they should have terminated based on this criterion (also affects successes/failures of flyouts)
1.2.2	Aerodynamics/ Kinematics	Error in logic for processing point-mass data when missile aero tables are read (misspelled array name, misplaced ENDIF)	Unknown
		Past values of AOA, sideslip, and roll angle set to current value	AOA autopilot relies on difference between past and present values and will not function correctly; effect on other functions unknown
		The calculation of side force coefficient per unit angle-of-sideslip as a function of AOA and mach number has the order of arguments reversed (AOA and mach number)	The wrong value for side force coefficient will be returned. If AOA is greater than the maximum mach number in the look-up table, there will be an out-of-bounds error and the program will terminate.
6.1	Guidance	There are several errors in the guidance scheme for constant flight-path angle in azimuth	Does not produce desired flight path
		Pseudo-kinematic link (PKL) guidance - Error in transforming input vector through multiple rotations	Applies to PKL guidance only; only final rotation applied; effect unknown
6.2	Autopilot	There are several errors in the autopilot model (incorrect sign on forward accelerometer feedback; past and current values for AOA and sideslip equal; sideslip calculated with sine instead of tangent; roll autopilot feedback provided by roll rate rather than rate-of-change of roll rate)	Current implementation can lead to instabilities and failure
		Torque-balance control autopilot - incorrect conversion from torque to angular demands (units)	Unknown
		Synthetic-stability control autopilot - pitch and yaw deflections erroneously multiplied by sin45	Actuator gain is reduced to 70% of correct value; effect unknown
All	All	There are numerous errors reported on launch zone generation (variable initialization, inconsistent conditions, boundary condition problems, mixed units)	Improper search termination; inappropriate initial conditions for some launch attempts; other effects unknown

3.4 IMPLICATIONS FOR MODEL USE

The models developed and distributed by NAIC inherently account for the assumptions and limitations listed above. Users operating within the constraints for use specified by NAIC in the documentation for a particular model can expect the model output to be representative of the system being simulated.

For a user developing new threat models, or modifying existing ones, the assumptions, limitations, and errors above may have a significant impact. Developers should be aware that some of the generic functions present in TRAP have not been sufficiently exercised or tested. For example, while claims have been made that the realistic AI radar model produces accurate results as a stand-alone model, its capability in TRAP has not been sufficiently tested and the user is advised in the documentation not to use it. In any case, the RCS table lookup code has known problems and is currently commented out forcing the user to set a single value RCS in the POLICY routine. Problems have also been identified with the IR seeker model. The calculations that determine the target aspect angle for the look up of IR signature are incorrect, and the code to calculate atmospheric transmittance is not yet operational. The user is advised to be cautious when using the IR seeker model, and to input a constant IR signature for modeling of IR targets. Numerous problems have been reported on the autopilot FE, and the user is cautioned to carefully look at the current models before selecting one to represent the operation of a specific system.

While TRAP will be useful for single flyouts of previously developed models, numerous problems have been identified with both the binary and smart search options used for launch envelope generation. The user should fully understand the methods involved before selecting this option.